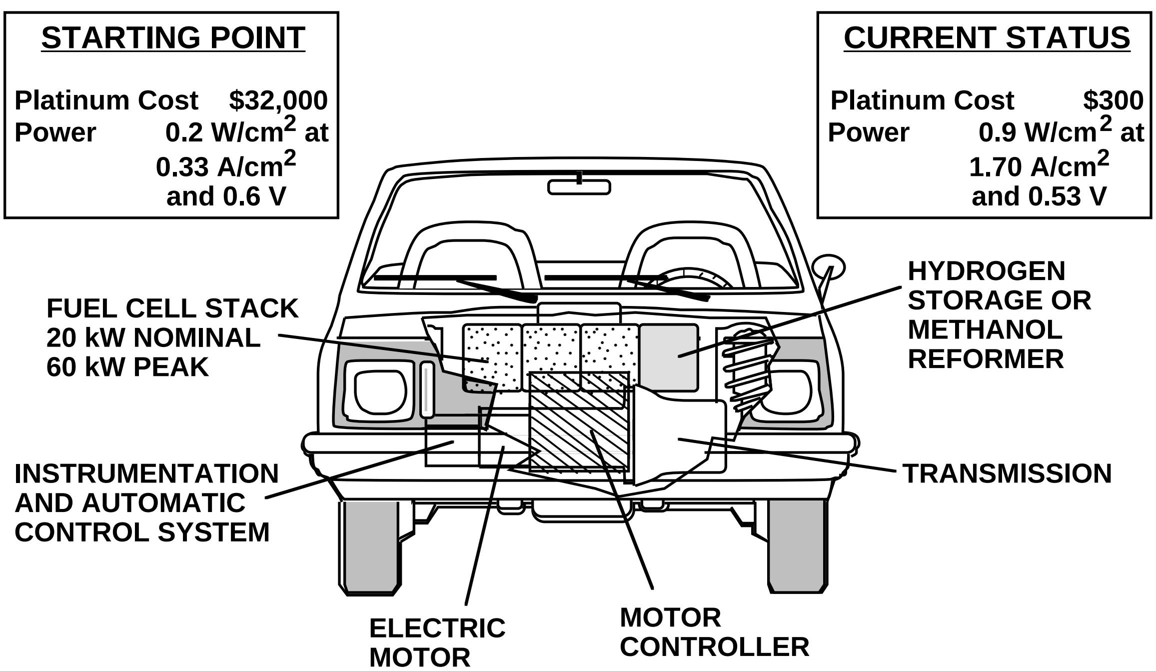
Polymer Electrolyte Fuel Cell Development

Los Alamos National Laboratory's Contributions in Core Research and Development

Mission

Conduct the basic and applied research necessary to bring polymer electrolyte membrane fuel cell technology to the performance and cost levels required for widespread use in transportation. Collaborate with the private sector in technology development and implementation.

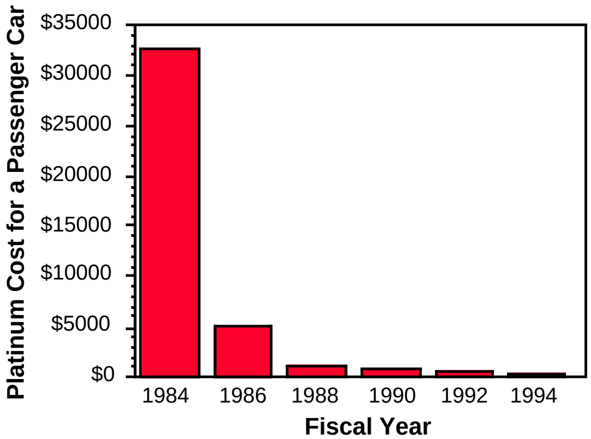


Materials Science and Technology Division

Electronics Research Group

Cost Is a Major Factor in PEM Fuel Cell Commercialization

The Core Research Program at Los Alamos has addressed critical issues leading to reduced cost of fuel cell stack components. Transportation applications of fuel cell technology place stringent requirements on the cost of the fuel cell stack. For markets such as electrical power generation for local utilities, fuel cell stacks will be a preferred choice when the installed cost is reduced below $2000/kW. Transportation applications will require perhaps another order of magnitude in cost reduction.



Cost of Fuel Cell Catalyst

Our most important achievement has been the reduction in platinum required for the catalyst in a fuel cell. This plot shows the cost of platinum for an 80 kW peak passenger car power plant as a function of time. The improvements result from the use of ultra-small platinum particles in a carefully engineered electrode layer on the membrane of the fuel cell. Not only did we dramatically reduce the platinum loading, we simultaneously improved the fuel cell power density by a factor of 4.

Fuel Cell Stack Component Costs

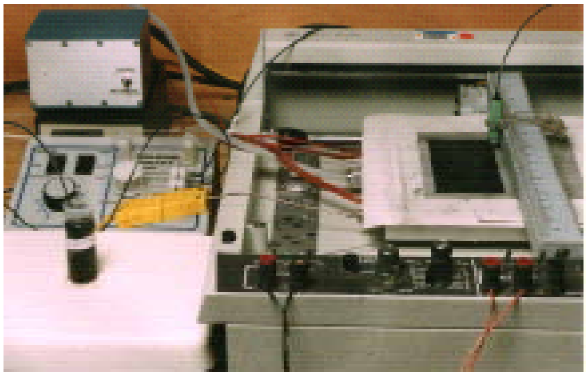
Los Alamos has analyzed the cost of materials for a fuel cell stack. This table shows the cost of the primary components based on our technology and estimates the cost of materials in mass production. Further improvements may be possible through a concerted effort in component development.

Active Area Components	Current Costs ($/sq ft)	Mass Production ($/sq ft)
Bipolar Plates		
Separators (1.5 x)*	2	1
Flow Fields (2.5 x)*	50	2
Membrane/Electrode Assemblies		
Backings (2 x)**	300	3
Membrane	80	4
Catalyst (0.25 mg Pt/cm^2)	40	4
Total $/sq ft active area	850	21
$/kW @ 0.5 W/cm^2	1830	45

*Includes 0.5 cooling plates per cell
**One backing for each electrode

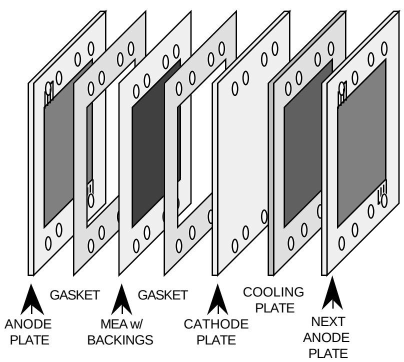
Technology Improvements Are Required to Insure High Performance from Easily Manufactured Fuel Cell Components

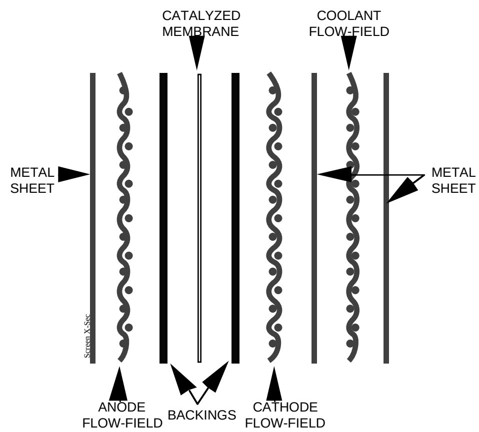
We are actively pursuing component development to demonstrate scaling of our fuel cell technology to cell areas commensurate with transportation and stationary power applications. In the process, we are examining approaches to low-cost components such as flow fields and backings.



Automated Manufacture of Membrane Electrode Assembly

Los Alamos has developed an automated process for the application of the catalyzed electrode to the membrane. The simple process shown here could be readily adapted to a high-speed manufacturing approach.





Low Cost Components Have Been Designed and Tested

Flow fields, cooling plates, membrane electrode assemblies, and anode and cathode plates all need to be designed for performance, corrosion resistance, and low cost. The left-hand drawing shows readily machined components based on a unipolar design. The right-hand drawing shows an extremely simple and cost-effective design based on using stainless steel screens for flow fields. The second design has advantages in cost and weight, but suffers somewhat relative to the first design in fuel cell performance. Nevertheless, such simple designs may prove adequate and cost effective for some applications.

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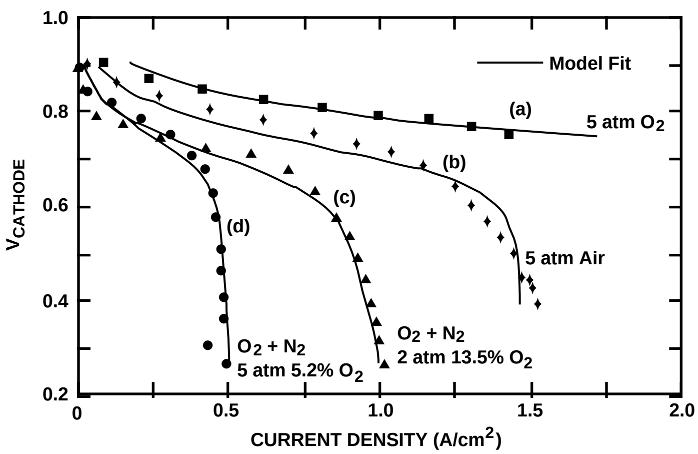
Performance Is Critical: Fuel Cells Must Compete with Alternative Means of Power Production

Whether the application is in transportation or stationary or portable electrical power generation, fuel cells must demonstrate a level of performance that exceeds alternative technologies. Depending on the application, the critical criterion may be efficiency, environmental impact, energy density of the power generation system, or the type of fuel available. We have invested substantial effort in developing fuel cell technology to address critical performance issues.



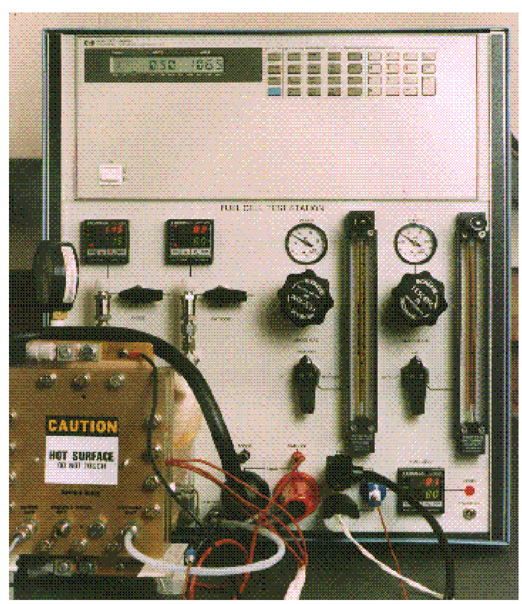
Fitted Parameters:
Cathode catalytic activity @ 0.9 V: 90 mA/cm^2
dV/dlogJ: 85 mV/decade
σ = 0.0013 S/cm (protonic cond. in catalyst layer)
DC* = 1.9 x 18^{-8} mol/cm-s-atm (gas perm. in catalyst layer)
Backing porosity: 0.25 - 0.19 (assuming zero tortuosity)

Characterization of Single Cells Is Essential in Developing Fuel Cell Technology

Water management, membrane thickness, electrode impedance, catalyst dispersion, fuel stream impurities, temperature, and other factors affect the performance of fuel cells. The key to understanding these factors is performing controlled experiments under realistic conditions, and establishing validated models to determine the critical factors for improved design. We have established a facility for fuel cell testing and a modeling capability to describe the results. The plot to the left demonstrates our ability to accurately model fuel cell performance over a broad range of operating conditions.

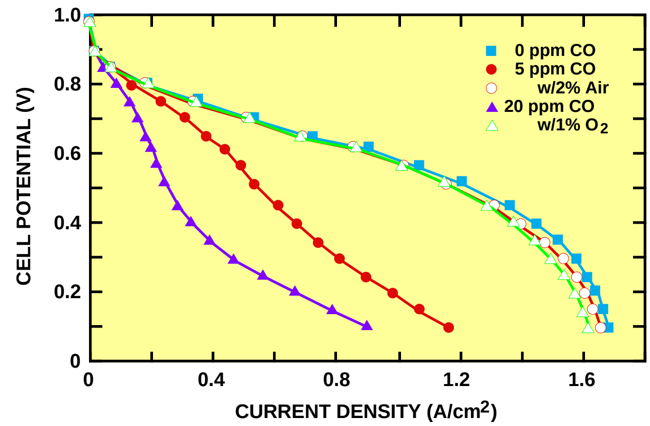
Full Scale Operation of Fuel Cells Has Been Demonstrated

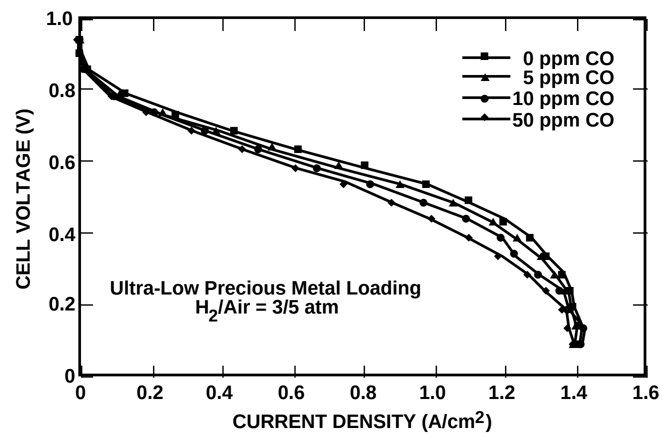
We have scaled our fuel cell components to 100 cm^2 devices, approaching areas needed in transportation applications. The picture shows such a cell producing over 50 W, attached to our standard fuel cell test station. The cell is operating at 80° C, $P_{air} = P_{hydrogen}$ = 30 psig. The air utilization is 50%, and the hydrogen utilization is 90%.



Operation on Reformed Fuel Is Anticipated for Most Fuel Cell Applications

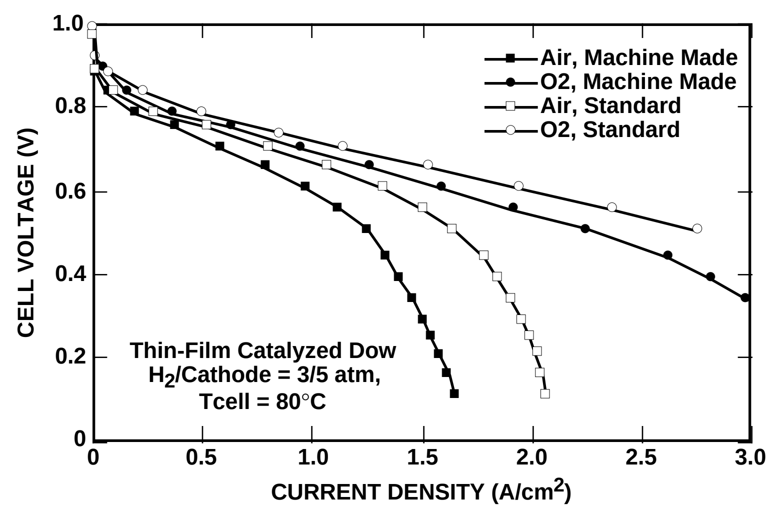
Fuel considerations are of paramount concern in most fuel cell applications. There is no existing infrastructure for hydrogen distribution, nor is there an efficient storage mechanism for hydrogen. The first application of fuel cells will probably invoke hydrogen produced through reforming either methanol or natural gas. The reforming processes result in impurities in the fuel stream. The most prevalent is CO, which poisons the anode catalyst. (Note the negative effect of as little as 20 ppm CO in the fuel stream indicated in the figure to the right.) We have developed two approaches that alleviate the adverse affects of CO poisoning: Anode air injection and a special operational mode (patent application submitted). The polarization curves to the right show the ability of a fuel cell to recover essentially full performance using these approaches.





The Design of Low Cost Components for Fuel Cells Remains a Critical Issue

Backings, bipolar plates, flow fields, and other fuel cell components all must be designed for ease of manufacture and optimal performance. We are developing designs for these components and testing their performance against the best laboratory-scale designs. The plot below shows how well one type of machine-made backing material performed compared to our laboratory standard.



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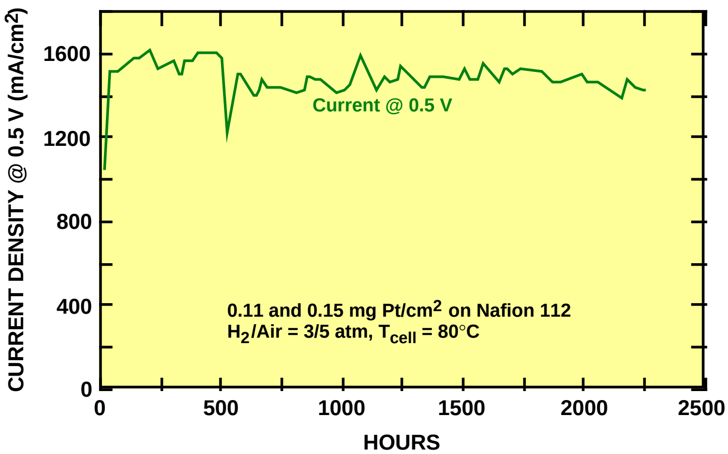
Fuel Cells Must Be a Reliable Replacement for Existing Technology

Internal combustion engines have lifetimes that enable consumers to drive their cars over 100,000 miles. Consumers also expect reliable performance from their electric utility service. Fuel cells must meet these consumer expectations if they are to displace existing technologies.

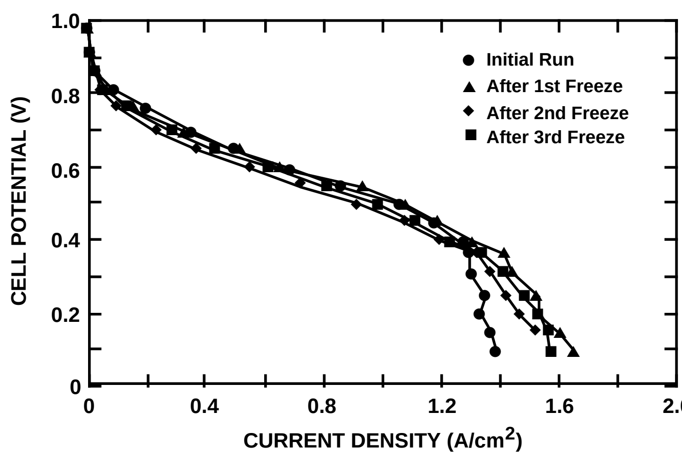


Los Alamos Has Demonstrated Long-Term Survivability of Membrane Electrode Assembly Technology

The plot to the left shows sustained operation of an ultra-thin membrane electrode assembly in a single cell at operating conditions necessary for transportation applications. Over 2000 hours of operation is shown, with negligible change in performance. At 25 mph, it would take 4000 hours to go 100,000 miles. We have tested membranes to over 4000 hours.

Fuel Cells Must Be Able to Survive Adverse Environmental Conditions

One practical consideration in transportation applications of fuel cells is the ability of the fuel cells stack to withstand temperature extremes. We have subjected a fuel cell to multiple freeze-thaw cycles to look for adverse affects. The results are shown in the plot to the right. Our fuel cell design is robust against several freeze-thaw cycles.



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The Los Alamos Core Research Fuel Cell Team Has Developed a Strong Reputation for Effective Technology Transfer

Dr. Mark K. Debe
Sr. Research Specialist
3M Corporate Research Center

"Recently I had the opportunity to spend two days with Dr. Shimshon Gottesfeld's fuel cell and electrochemistry research and development group at LANL. It is with pleasure that I take this opportunity to acknowledge their outstanding capabilities and the exceptional services they extended to me.

"As a result of their significant professionalism and capabilities, we were able to very effectively evaluate a new membrane-electrode assembly concept in a mere day and a half..."

Bamdad Bahar
Business Leader
Filtration Technologies
W.L. Gore & Associates

"We were particularly impressed with LANL's excellent and timely feedback. LANL was unique in helping us through our early development of [fluoroionomer composites], providing us with useful test data and, in effect, facilitating the generation of a new commercial product... In my humble opinion, it is this type of Government/Industry collaboration which will ensure U.S. leadership in this particularly important, perhaps strategic, area of technology."

Partnership Opportunities

- Cooperative Research and Development Agreements
- Nondisclosure Agreements
- Industrially Sponsored R&D
- Professional Consultation
- Small Business Innovative Research Support
- Joint Proposals

Why come to Los Alamos for Polymer Electrolyte Fuel Cell Technology?

- We understand the major issues that influence cost in PEM fuel cell technology and have developed state-of-the-art technology to reduce the costs, especially those associated with electrocatalysts.
- We have an active research and development program addressing low cost, easy to manufacture fuel cell components for a high-performance stack.
- We have a state-of-the-art test and evaluation program, including computer simulation and materials testing, for fuel cell performance. This activity includes reliability issues, water management, fuel impurity tolerance, and other aspects of fuel cell performance.
- We are effective at working with industrial partners to solve their fuel cell-related problems.
- Recently, we have turned substantial attention to direct-methanol fuel cells. Ask us about our results in this exciting new chapter of Los Alamos work on polymer electrolyte fuel cells.

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